XVII. *Colour Photometry.*—Part II. *The Measurement of Reflected Colours.*

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[Plates 20–23.]

§ XXVII. *Old Method of Measurement.**

In our first paper on this subject we have shown how the luminosity of the spectra of various sources of light can be measured; and the present paper is an extension of the subject, dealing with the measurement of the light reflected from bodies in terms of the colours of the spectrum of the light illuminating them. By the method which we adopted in the first part of "Colour Photometry" this can be effected, and, indeed, we carried that out in several instances. The method then employed was very simple. If we wished to measure the illuminating value of the spectrum of light reflected from a metal, we placed it at an angle in front of the slit of the spectroscope, so as to reflect the light from the crater of the positive pole of the electric light through the photometer, and measured the luminosity of each part of the spectrum thus formed by the method we indicated in our paper. Again, in experimenting with Gorham's discs, such as Maxwell employed, where it became necessary to determine the light reflected from the different coloured papers or cards used in the discs, the plan first adopted was to replace the receiving shadow screen of zinc oxide (see § VI) by the coloured papers, and again to make a luminosity measurement. This plan answered its purpose, but it was rather laborious. When two or three colours are combined by rotation to form a grey, and black and white sectors are combined to match that grey, in order to ascertain the total luminosity of each colour, the angular value of the sectors being known, it is necessary to refer the luminosity to that of some standard reflecting surface, which is naturally a white one. As the comparison light is coloured by falling on coloured paper, the value of the spectrum reflected from such paper could not by this first method be directly compared with that reflected from the white screen. In the case of a coloured screen, the curve of spectrum luminosity would therefore have to be reduced to that in which the comparison light was white. This difficulty was surmounted by making half the receiving screen white and half of the

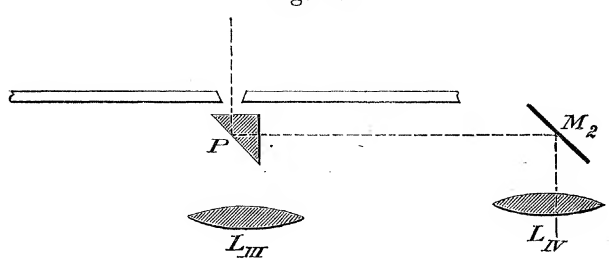
* The numbering of the paragraphs and figures in this paper is a continuation of that of Part I.—Bakerian Lecture, 'Phil. Trans.,' 1886.

colour whose luminosity was to be measured, illuminating the shadow of the rod thrown on the coloured paper by the spectrum colour, and that thrown on the white card by the white light reflected from the surface of the first prism (§ XXVI). This did away with any reduction or calculation; but still an objection remained, as, for definite comparison, it was almost necessary that the same observer should always make the measurement.

§ XXVIII. *Revised Method.*

One of us having to measure the colour of various water-colour pigments for a Government enquiry on their fading, it became important to introduce some other plan by which the same end could be attained. Various artifices were tried, but finally we came to the conclusion that a spectrum photometer was necessary, and on these lines the following various modifications of our original apparatus were devised by one of us (Captain ABNEY):—The collimator, prisms, and camera were at first kept as in the colour photometer; but for the camera lens was substituted a lens divided into equal segments, which could be centrally separated, as in a heliometer. The light coming through the last prism fell as a square patch on this divided lens, and the two segments were separated so that two spectra fell on the focussing screen, one above the other. A slit in a card was then passed across this double spectrum, and any required ray

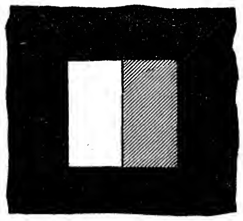
Fig. 13.



was isolated. P is a right-angled prism attached by a rod to the top half of the slit so as to reflect the ray from the top spectrum to one side, whilst the ray of the same colour from the bottom spectrum traversed the slit unimpeded and fell on the lens L_{III}, forming a patch of monochromatic light on the screen. The ray which was reflected by P was again reflected by a mirror M_2, and fell on another lens L_{IV}, by which a similar patch of monochromatic light could be made to fall over the patch formed by L_{III}. Each of these monochromatic rays cast a shadow of a rod, placed in front of the receiving screen, and the shadow cast by each spectrum was illuminated by light of the same colour coming from the other. To measure the value of a coloured paper, the screen was made half with a white card and half with the coloured paper, as in the figure. The shadows were made to touch at the intersection of the card and coloured paper. In front of the light which illuminated the shadow cast on the white card was placed a motor rotating movable sectors, as described in our paper recently read before

the Royal Society.* Two methods presented themselves of equalising the illumination of the shadows—first, by moving the slit across the spectrum whilst the sectors rotated with a fixed aperture; or, secondly, by placing the slit at known places in the spectrum and equalising the illumination of the shadows by altering the aperture of the sectors. In cases where the absorption of the spectrum by the colour increased rapidly, the first method was most convenient, but where the absorption was very gradual, the latter method was found to be most accurate, and was most usually adopted.

Fig. 14.



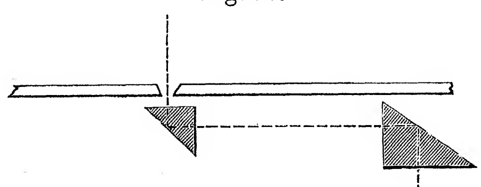
This plan of producing the two spectra, at first sight, seemed everything that could be wished, but a difficulty occurred which rendered a further modification advisable, for it was found that the two spectra were not of proportionate intensity throughout. This was discovered in following out the necessary order of experiment; which was, first, to compare the luminosity of the spectrum on the coloured paper with that on the white card, and then to compare the values of the two spectra to one another by throwing both shadows on white card. If the spectra were of proportionate intensity throughout, it should only have been necessary to measure the relative values of any one ray, and the same ratio ought to have been obtained for any other. When trying this, however, it was found that if the two shadows were cast by rays in the red end of the spectrum, there was decreasing value in one of the spectra towards the violet. In fact, in the extreme violet the spectrum of one was only about three-fourths as bright as that of the other. The cause of this difference became apparent when examining the matter. The half lens which focussed one spectrum received the rays which had passed through the thinnest part of the prisms, whilst that focussing the other had passed through the thickest parts. The difference in the ratio of the brightness at different parts of the spectrum was traced to the different amounts of light absorbed by the different thickness of glass traversed. Any slight shift in the position of the line of separation of the lens altered the ratio of absorption, and, as in some cases such a shift could not well be avoided, the method, though practicable, was scarcely practical. It became evident, then, that some means must be adopted of forming each spectrum with the light which had traversed the same thickness of glass.

* "Photometry of the Glow Lamp," 'Roy. Soc. Proc.,' vol. 43

§ XXIX. *Apparatus finally Adopted.*

After many experiments, it was determined to fix a double-image prism behind the collimating lens. This double-image prism of Iceland spar was made by Mr. A. Hilger, with his usual ability, and was so adjusted that when the central half of the collimator slit was used the two spectra, while of the same length, were separated by one-eighth of an inch on the focussing screen, the ordinary camera lens being employed. The reflecting apparatus was also slightly altered by substituting for the fixed reflector a second right-angled prism attached to the card so as to reflect the light through the second lens L_{IV}. There was a great advantage in this, for with the fixed reflector the colour patch travelled across that formed by the direct beam, and thus the same parts of the image of the prism's face were not always superposed. The plan of attaching the reflector to the slit card got over this difficulty, and rendered the measurements more accurate.

Fig. 15.



§ XXX. *Adjustment of the Instrument.*

The adjustment of the instrument, when using the double-image prism, required care, and the following plan was adopted. The whole slit of the collimator was illuminated by light from the arc in which lithium and sodium were vaporised. The two spectra now overlapped, since the separation of one-eighth of an inch was only obtained when the slit was one-fourth of an inch in height. The bright lines of the lithium in the two spectra were then made to coincide by turning the double-image prism; the central portion of the slit in the collimator was then used, and the slit in the card passed through the two spectra. If the collimator slit was properly adjusted in the vertical and a bright line in one spectrum traversed the centre of, say, the top part of the aperture in the card, the same bright line in the other spectrum ought to traverse the centre of the bottom part of the aperture. If this were not so the collimator was readjusted, and the same operation gone through. To make doubly certain that the adjustment was correct, the direct and reflected rays from different parts of the continuous spectrum of the positive pole were made to form superposed patches on white card, and shadows of a rod were cast by each so as to touch. The rotating sector was placed in front of the brightest, and the illumination of the two equalised. If the same aperture of sector equalised the illumination throughout the spectrum the adjustment was considered as complete, if not, a new adjustment was made till such was the case. It was found in practice that a very good adjustment could be

made by noting if the colours of the two shadows were of exactly the same hue, more especially in the transition between orange and green, and in that from the blue-green to blue. The slightest departure from true adjustment invariably showed itself in these two parts of the spectrum. We should not hesitate to adjust the instrument by this means alone, though in all the measures taken the comparison of the two spectra on white card was invariably made.

§ XXXI. *Exclusion of Extraneous Light.*

There is another point of special importance to be attended to, viz., the exclusion of all extraneous light from the receiving screen. If two shadows are to be compared together, when the whole of the screen is white or of the same colour, the admission of extraneous light is not detrimental; but, if one shadow falls on a white ground and the other on what in white light is a coloured ground, it is absolutely necessary to keep the screen free from all light except that forming the shadows.

It was curious to note the change in colour produced on the coloured half of the screen when illuminated partially by a portion of the spectrum weak in luminosity, and partially by weak white light. It was absolutely impossible to match the colours, when even a very small percentage of white light fell on the screen. The whole apparatus was placed in a darkened room, the electric light being in a lantern. Extraneous light was excluded by placing the screen at the end of a box 18 inches wide, 12 inches deep, and 2 feet long, the interior being blackened. A white card placed at the end of the box was then invisible when the electric light was burning and the slit in the card was placed beyond the limit of the spectrum.

§ XXXII. *Width of Slit Employed.*

The great point in measuring accurately was to adjust the luminosity so that it was of such brightness that the eye could readily distinguish any small difference in the brightness of the illuminated shadows. This was effected by altering the width of the slit in the collimator from time to time. When the brightest part of the spectrum was under measurement, the width was about $\frac{1}{150}$th of an inch, and, when the least luminous parts, it was opened to about $\frac{1}{30}$th of an inch. The slit in the card remained invariable, being about $\frac{1}{25}$th of an inch in width. The screen was placed 3 feet from the slit card.

§ XXXIII. *Experiments with Emerald Green, Vermilion, and Ultramarine.*

The first experiments were conducted to ascertain the composition of the grey light given by a set of discs of emerald green, vermilion, and French ultramarine. Discs of these colours, 6 inches in diameter, were prepared; and a larger pair of black and white discs arranged on the same axis. The sectors of the three colours and of the

black and white were altered by trial to match when rotated in the patch of white light formed by the recombination of the spectrum. When these same coloured discs were rotated in day light or gas light they, as was to be expected, no longer formed a grey, but had a predominant tint of green or red; and the illuminating value differed from that of the black and white discs. The alteration in hue and luminosity in passing from one source of light to another, showed the necessity of using the same source for making the match and for measuring the luminosity of the colours. In adjusting the apparatus as explained above, with both parts of the receiving screen white, we found that the rotating sectors had to be set with an aperture of 69° in order to get a balance throughout the spectrum. Measurements were then made throughout the spectrum of the intensity of light reflected from each of the coloured cards, the aperture of the rotating sectors at each part giving the relative amount of light reflected, the maximum value being 69°.

§ XXXIV. *Calculations of Luminosity.*

The mean angular values of the coloured cards in the rotating disc which matched the white and black disc were as follows:—Emerald green, 133°·7; vermilion, 96°·6; French ultramarine, 129°·7. In order, therefore, to get the comparative amount of light reflected from each coloured sector in the disc in terms of that reflected from the emerald green, the readings of the red card were reduced in the ratio of 96·6/133·7, or multiplied by ·722, and those of the blue by 129·7 / 133·7, or ·97, those of the green card being unaltered. From these figures the curves on fig. 16 were plotted; the straight line at 69 being taken to represent the amount of light at each part of the spectrum which was reflected from a white card sector of 133°·7, the ratio of the ordinates of the other curves to 69 would indicate the proportion of each ray reflected from the coloured sector as compared with that from a white sector of 133°·7.

From these curves the luminosity curves in Plate 20, fig. 17 were constructed. The outer curve is the normal curve of white light, as given in Part I. of "Colour Photometry' (§ VIII. and fig. 3), the scale of the spectrum being the same. The curves for the colours were then made, their ordinates bearing the same proportion of those of the outer curve that those of the curves in Plate 20, fig. 16 bear to 69.

Emerald Green. Sector taken as unity.

Original readings.		Reduced from plotted curve.		Luminosity curves.	
Scale number.	Reading.	Scale number.	Reading.	White.	Emerald green.
42·80	5·0	43·00	5·0	2·0	·10
43·30	5·0	44·00	5·0	16·0	1·20
44·30	6·5	45·00	8·0	65·0	5·20
45·32	9·5	45·50	11·0	84·0	13·40
45·83	14·5	45·80	13·0	90·0	17·00
46·85	23·0	46·00	14·0	94·0	18·90
47·36	27·0	46·35	17·5	97·0	24·60
47·87	34·0	46·85	23·0	99·5	33·20
48·38	40·0	47·10	25·0	100·0	36·20
48·89	43·5	47·35	27·5	99·5	39·60
		47·50	30·0	99·0	43·00
49·45	49·0	47·85	34·0	98·0	48·30
49·91	50·0	48·90	44·0	82·0	52·30
50·42	52·0	49·40	49·0	70·0	50·00
50·93	50·0	49·90	51·0	48·0	35·50
51·44	48·0	50·40	52·0	31·0	23·30
51·95	46·0	50·90	50·0	20·5	14·80
52·46	41·0	51·90	46·0	10·0	6·60
53·48	34·0	52·90	38·0	5·5	3·00
54·50	24·0	54·00	28·0	3·5	1·40
55·26	20·0	54·50	24·0	2·8	·80
57·05	15·0	55·00	21·0	2·1	·60
58·07	15·0	57·00	15·0	·9	·20
		58·00	15·0	·6	·13

Vermilion. Sector = ·722 of Green.

Original readings.		Reduced from curve.		Reading reduced by ·722.	Luminosity curves.	
Scale number.	Reading.	Scale number.	Reading.		White.	Vermilion.
42·80	40·0	43·00	45·0	36·0	2·0	·80
43·30	50·0	43·50	55·0	39·0	5·0	
43·80	60·0	44·00	61·0	44·0	16·0	10·10
44·30	65·0	44·50	66·0	47·5	37·0	25·50
44·80	65·0	45·00	66·0	47·5	65·0	44·70
45·30	62·5	45·20	66·0	47·5	74·0	51·00
45·80	60·0	45·50	65·0	47·0	84·0	57·00
46·35	45·0	45·80	60·0	43·0	90·0	56·00
46·85	29·0	46·00	55·0	40·0	93·5	53·00
47·60	18·0	46·35	45·0	32·5	97·0	45·70
47·35	14·0	46·85	29·0	21·0	99·5	30·00
47·85	9·5	47·10	21·0	16·0	100·0	23·20
49·50	7·0	47·35	14·0	9·0	99·5	13·00
52·90	4·0	47·85	9·0	6·5	98·0	9·20
57·00	4·0	48·90	7·0	5·0	82·0	6·00
58·50	4·0	49·40	6·0	4·5	70·0	4·50
		49·90	5·5	4·0	48·0	2·80
		50·90	5·0	3·5	20·5	1·00
		51·90	4·0	3·0	10·0	·40
		52·90	4·0	3·0	5·5	·20
		54·00	4·0	3·0	3·5	·15
		55·00	4·0	3·0	2·1	·10
		57·00	4·0	3·0	·9	·07
		58·00	4·0	3·0	·6	·03

French Ultramarine. Sector = ·97 of Emerald Green.

Original readings.		Reduced from plotted curve.		Reduced to ·97 reading.	Luminosity.	
Scale number.	Reading.	Scale number.	Reading.		White.	Blue.
42·80	3·0	43·00	3·5	3·4	2 0	·10
43·30	4·0	44·00	6·0	5·9	16·0	1·40
43·80	6·0	45·00	4·0	3·9	65·0	3·80
44·30	5·5	45·50	4·0	3·9	84·0	5·00
44·80	4·0	45·80	4·0	3·9	90·0	5·30
48·90	5·0	46·00	4·0	3·9	93·5	5·50
49·40	6·5	46·35	4·0	3·9	97·0	5·70
49·90	9·0	46·85	4·0	3·9	99·5	5·80
50·40	11·0	47·10	4·5	4·2	100·0	6·10
50·95	14·0	47·35	4·5	4·4	99·5	6·40
51·45	17·0	47·85	5·0	4·9	98·0	7·00
51·95	20·0	48·90	5·5	5·4	82·0	6·30
53·00	24·0	49·40	6·5	6·1	70·0	6·10
54·00	27·0	49·90	9·0	8·7	48·0	6·00
55·00	26·0	50·90	14·0	13·5	20·5	4·00
56·00	26·0	51·90	20·0	19·5	10·0	2·80
58·00	26·0	52·90	24·0	23·3	5·5	1·85
		54·00	26·0	25·0	3·5	1·30
		55·00	26·0	25·0	2·1	·80
		57·00	26·0	25·0	·9	
		58·00	26·0	25·0	·6	·20

The above tables give the figures on which the curves were based. Column I. gives the spectrum scale, and Column II. the original readings. Columns III. and IV. give the adopted readings at the different scale numbers. Column V. gives, in the cases of red and blue, the ordinates reduced in proportion to the angles of the sectors, as explained above. The last column but one gives the ordinates of the curve of luminosity of the light reflected from white card, which is the outer curve in fig. 5 (Part I.). The last column gives the ordinates of the luminosity curves of the colours.

Reverting to fig. 17, if the area of the outer curve, which is 534, represents the total amount of light reflected from a white card sector of 133°·7, the areas of the curves for the green, red, and blue, which are respectively 221, 156·3, and 47·9, represent the amount of light from the coloured sectors; and the total of these, or 425·2, represents the amount of light reflected from the disc made up of the coloured sectors.

Now the black and white disc which, when rotated, matched the coloured disc, consisted of black and white in the proportions of 278 : 82, and we find that the black paper reflects 8·33 per cent. of white light; the proportion of white to the whole disc was therefore (82 + ·0833 × 278, or) 105 to 360, the amount of light reflected from the disc should therefore be represented by 105/133·7 of 534, or 419·4, a result coinciding within the limits of error of observation with that just obtained for the coloured disc.

Intensities.						Luminosities.				
Scale number.	Emerald green.	Vermilion.	French ultra-marine blue.	Sum of intensities.	Sum × ·37.	Emerald green.	Vermilion.	Ultra-marine blue.	Sum of lumino-sities.	Sum × ·37.
43·00	5·0	36·0	3·4	44·4	16·4	·10	·80	·10	1·00	·40
44·00	5·0	45·0	5·9	55·9	20·7	1·20	10·10	1·40	12·70	4·70
45·00	8·0	47·5	3·9	59·4	22·0	5·20	44·70	3·80	53·70	19·90
45·50	11·0	47·0	3·9	61·9	22·9	13·50	57·00	5·00	75·50	27·90
45·80	13·0	43·0	3·9	59·9	22·1	17·00	56·00	5·30	78·30	29·00
46·00	14·0	40·0	3·9	57·9	21·5	18·90	53·00	5·50	77·40	28·60
46·35	17·5	32·5	3·9	52·5	19·4	24·60	45·70	5·70	76·00	28·10
46·85	23·0	21·0	3·9	47·9	17·7	33·20	30·00	5·80	69·00	25·50
47·10	25·0	16·0	4·2	45·2	16·7	36·20	23·20	6·10	65·50	24·30
47·35	27·5	9·0	4·4	40·9	15·1	39·60	13·00	6·40	59·20	21·90
47·85	34·0	6·5	4·9	45·4	16·8	48·30	9·20	7·00	64·50	23·80
48·90	44·0	5·0	5·4	54·4	20·1	52·30	6·00	6·30	64·60	23·90
49·40	49·0	4·5	6·1	59·6	22·0	50·00	4·50	6·10	60·60	22·40
49·90	51·0	4·0	8·7	63·7	23·6	35·50	2·80	6·00	44·30	16·40
50·90	50·0	3·5	13·5	67·0	24·8	14·80	1·00	4·00	19·80	7·30
51·90	46·0	3·0	19·5	68·5	25·4	6·60	·40	2·80	9·80	3·60
52·90	38·0	3·0	23·3	64·3	23·8	3·00	·20	1·85	5·00	1·80
54·00	28·0	3·0	25·0	56·0	20·8	1·40	·15	1·30	2·85	1·05
55·00	21·0	3·0	25·0	49·0	18·1	·60	·10	·80	1·50	·60
57·00	15·0	3·0	25·0	43·0	15·9	·20	·04	·30	·54	·20
58·00	15·0	3·0	25·0	43·0	15·9	·13	·03	·20	·36	·15

The above table gives a summation of the ordinates at each point of the scale of the three coloured curves; in addition, the sixth and eleventh columns give the sum of the ordinates multiplied by ·37, which is the ratio between 133·7 and 360; and the resulting curves, which show graphically the combination producing the grey light, are No. IV. of figs. 16 and 17 (Plate 20).

For convenience of comparison, we have reduced the luminosity curves to the normal scale of wave-lengths, as shown in fig. 18, which has been made from the following table :—

Luminosity Curves reduced to the Normal Scale.

Scale number.	Wave-length.	Ordinates of luminosity curves.						
		I.	II.	III.	IV.	I_1.	II_1.	III_1.
43·00	699	·05	·43	·05	·53			
44·00	662	·75	6·30	·87	7·92	·04	·37	·05
44·50	645	2·00	14·20	1·40	17·60		1·00	
45·00	629	3·80	32·50	2·76	39·06	·32	2·75	·23
45·20	623	6·20	38·00	3·20	47·40		4·40	
45·50	614	10·50	44·50	3·90	58·20	1·88	7·90	·70
45·80	606	13·80	45·50	4·30	63·60	3·33	11·00	1·04
46·00	601	15·80	44·30	4·60	60·70	5·10	14·20	1·49
46·35	593	21·30	39·70	5·00	66·00	9·90	18·20	2·28
46·85	580	30·80	27·80	5·40	74·00	20·40	18·60	5·35
47·10	574	35·00	22·30	5·90	63·20	25·00	15·90	4·22
47·35	569	39·00	12·80	6·30	58·10	29·50	9·75	4·77
47·50	566	43·00	10·10	6·60	59·70	33·50		
47·85	560	50·00	9·50	7·20	66·50	51·70	7·80	5·95
48·90	540	60·00	6·90	7·30	74·20	53·50	6·10	6·48
49·40	530	61·00	5·50	7·50	74·00	57·40	5·10	6·85
49·90	521	45·50	3·60	7·70	56·80	45·50	3·60	7·70
50·40	512	31·50	2·10	6·70	40·30			
50·90	503	20·00	1·40	5·70	27·10			
51·90	488	10·30	·60	4·40	15·30			
52·90	475	5·10	·30	3·10	8·50			
54·00	464	2·50	·27	2·30	5·07			
54·50	459	1·50	·23	1·90	3·63			
55·00	454	1·20	·2	1·50	2·90			
57·00	436	·44						
58·00	428	·30						

§ XXXV. *Testing the Accuracy of the Measurements.*

Let us now consider fig. 16. The space between the horizontal line at 69 and that at the bottom of the diagram may be taken to represent white light, and that between any other two horizontal lines would, in the same way, represent degraded white or grey.

Evidently also the space between the combination curve No. IV. and the bottom line would represent grey, for it has been shown that, if all parts of the spectrum be combined in proportion to the ordinates of that curve, the result is grey. If now a horizontal line be drawn tangential to the highest point of the curve, the space between that and the bottom line would represent grey; and, as that between the curve and the bottom line represents grey, the difference of these two or the space between the curve and the tangential line must also represent grey: that is to say, grey should result from the combination of all parts of the spectrum in the proportions of the ordinates lying between the tangent and the curve.

This consideration suggested a good test for the accuracy of the method employed in the measurement of the colours, and of the proportion in which they should be combined to produce white (or grey). If the rays of the spectrum itself could be taken in the proportions in which they are reflected from any pigment, say emerald green, and recombined, the resulting light should be of the same colour as that reflected from the pigment. This was proved to be so in the following way :—A card

disc, about 24 inches in diameter, was taken, and commencing about 4 inches from its centre the scale of the spectrum was laid off on a radius. Concentric circles were drawn through the different points of the scale, and, from the centre as origin, angles were laid off proportionate to the height of the ordinates of the emerald green curve (fig. 16); the intersections of the lines forming these angles with the circles through the corresponding abscissæ gave a figure which was cut out of the disc (Plate 23, fig. 19). The latter being rotated in a proper position in front of the spectrum allowed the proper proportions of the different rays of the spectrum to pass through, and then, being recombined on the screen, produced the colour of the pigment. The identity of the colour with emerald green was proved by reflecting white light on to a square of paper coloured with that pigment placed near the colour patch. A similar mask (fig. 20) being cut out to correspond to the ordinates of the curve No. IV. taken above the tangent to its lowest point produced a grey patch on the screen.

(In the prismatic spectrum the rays are more or less curved; but, as their curvature will not correspond at all points to that of the disc, it is necessary, in order to obtain a correct result, to reduce the breadth of the spectrum by shortening the collimator slit.)

A further proof of the accuracy of the measurements was also adopted. The three discs were rotated with a larger white * disc on the same axis; a card, having the curvature of the outside circle of the coloured discs and a breadth the same as that of the rod usually employed, replaced the rod, and, as before, the rays from the two spectra cast shadows, one on the white rotating disc and the other on the rotating coloured sectors, which, it should be recollected, to the eye gave a grey. Measurements were made as before, and the readings being reduced proportionally to the white which would have been present when the black sector was rotated with the white sector, the curve No. V. in fig. 16 was obtained. At first it would appear that the brightness of the mixture was too great; but, as a matter of fact, it was not, for the white card employed in the experiment was slightly greyer than that used in the white disc which, when rotated with the black, gave the grey. It will be noticed that this curve is practically parallel to that obtained by the summation of the three luminosities; this appears to confirm its correctness. *If any curve gives a grey, then any other curve parallel to it will do the same.*

§ XXXVI. *Experiments with Yellow and Blue Discs.*

There are two favourite colours which are often used in class demonstrations to show the formation of a grey on their rotation in proper proportions. One is pale yellow chrome, and the other a French blue, also very pale. Discs were prepared with these colours, and the grey produced matched by black and white. The colours were subsequently measured by the plan already described; the following tables give the results of the measurements.

* The beam lighting this had passed through the rotating sectors black and white sectors, therefore, could not be used, since scintillation was produced.

Chrome Yellow.

Original readings.		Reduced from plotted curve.		Luminosity.	
Scale number.	Reading.	Scale number.	Height.	White curve.	Yellow curve.
42·80	60·0	43·0	61·0	2·0	1·70
43·80	61·0	43·5	61·0	5·0	4·40
44·30	63·0	44·0	62·0	16·0	14·40
44·80	63·5	44·5	63·0	37·0	33·80
45·30	63·5	45·0	63·5	65·0	60·00
45·80	63·0	45·5	63·5	84·0	77·30
46·85	61·0	46·0	62·5	93·5	84·00
47·35	63·0	46·5	60·5	98·5	88·50
47·85	66·0	47·0	61·5	100·0	92·00
48·90	63·0	47·5	64·0	100·0	92·70
49·90	55·0	48·0	66·0	95·0	91·00
50·95	47·0	48·5	65·0	88·0	82·90
51·95	39·0	49·0	61·5	80·0	71·20
52·45	35·0	49·5	58·0	67·0	56·30
52·95	30·0	50·0	54·5	43·0	33·90
54·00	23·0	51·0	46·5	19·5	13·10
55·00	21·0	52·0	38·5	9·5	5·30
56·00	21·0	53·0	30·0	5·5	2·40
57·00	21·0	54·0	23·0	3·5	1·10
58·00	21·0	56·0	21·0	1·5	·45
		58·0	21·0	·6	·18
					Area = 464

Light Blue.

Original readings.		Reduced from curve.		Height × 1·13.	Luminosity.	
Scale number.	Reading.	Scale number.	Height.		White curve.	Blue curve.
42·80	13·0	43·0	13·0	14·5	2·0	·40
43·80	13·0	43·5	13·0	14·5	5·0	1·00
44·80	10·0	44·0	12·0	13·6	16·0	3·15
45·80	8·0	44·5	11·0	12·4	37·0	6·40
46·85	9·0	45·0	9·5	10·7	65·0	10·00
47·35	10·0	45·5	8·5	9·6	84·0	11·60
48·40	11·5	46·0	8·0	9·0	93·5	12·10
49·40	15·0	46·5	8·5	9·6	98·5	13·60
49·90	17·0	47·0	9·0	10·2	100·0	14·65
50·40	21·0	47·5	10·0	11·3	100·0	16·20
50·95	25·0	48·0	11·0	12·4	95·0	17·10
51·95	30·5	48·5	12·0	13·6	88·0	17·20
53·00	34·0	49·0	13·5	15·2	80·0	17·80
53·50	36·0	49·5	15·5	17·5	67·0	16·90
54·00	38·0	50·0	18·5	20·9	43·0	14·00
55·00	38·0	51·0	25·0	28·2	19·5	8·00
56·00	37·0	52·0	30·5	34·5	9·5	4·60
58·00	36·0	53·0	34·5	39·0	5·5	3·10
		54·0	38·0	42·9	3·5	2·20
		56·0	38·0	42·9	1·5	·90
		58·0	36·0	40·7	·6	·35
						Area = 92·8

Scale number.	Intensities.				Luminosities.			
	Chrome yellow.	Light blue.	Sum.	Sum × ·47.	Chrome yellow.	Light blue.	Sum.	Sum × ·47.
43·0	61·0	14·5	75·5	35·48	1·70	·40	2·10	1·00
43·5	61·0	14·5	75·5	35·48	4·40	1·00	5·40	2·54
44·0	62·0	13·6	75·6	35·58	14·40	3·15	17·55	8·25
44·5	63·0	12·4	75·4	35·28	33·80	6·40	40·20	17·10
45·0	63·5	10·7	74·2	34·87	60·00	10·00	70·00	32·90
45·5	63·5	9·6	73·1	34·35	77·30	11·60	88·90	41·80
46·0	62·5	9·0	71·5	33·60	84·00	12·10	96·10	45·20
46·5	60·5	9·6	70·1	32·95	88·50	13·60	102·10	47·94
47·0	61·5	10·2	71·5	33·60	92·00	14·65	106·60	50·10
47·5	64·0	11·3	75·3	35·18	92·70	16·20	108·90	51·18
48·0	66·0	12·4	78·4	36·85	91·00	17·10	108·10	50·81
48·5	65·0	13·6	78·6	37·05	82·90	17·20	100·10	47·04
49·0	61·5	15·2	76·7	36·05	71·20	17·80	89·00	41·83
49·5	58·0	17·5	75·5	35·48	56·30	16·90	73·20	34·40
50·0	54·5	20·9	75·4	35·28	33·90	14·00	47·90	22·51
51·0	46·5	28·2	74·7	35·11	13·10	8·00	21·10	9·92
52·0	38·5	34·5	73·0	34·31	5·30	4·60	9·90	4·65
53·0	30·0	39·0	69·0	32·43	2·40	3·10	2·50	1·17
54·0	23·0	42·9	65·9	30·91	1·10	2·20	3·30	1·55
56·0	21·0	42·9	63·9	30·03	·45	·90	1·35	·66
58·0	21·0	40·7	61·7	29·00	·18	·35	·53	·26
							Area	= 261·7

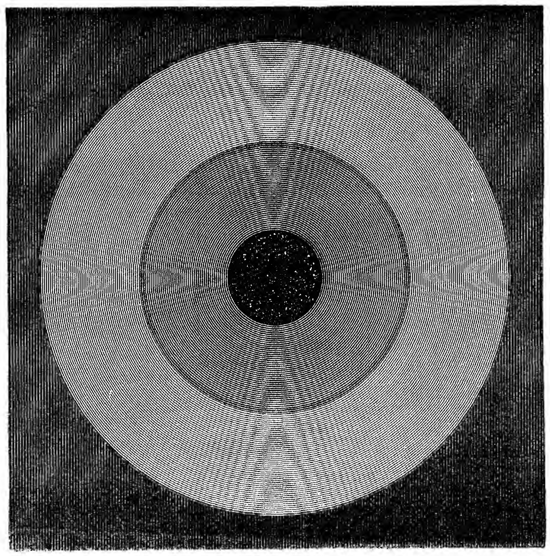
In this case the chrome yellow was taken as the standard. The chrome yellow required 169° of the disc, and the blue 191°; hence, the ordinates of the blue were multiplied by 1·13. Curves I. and II. in fig. 21 (Plate 21) give graphically the intensities of these two colours, as also Curve III. the sum of the intensities. It will be seen that there is a deficiency in the yellow and in the blue and violet, which together will give a grey, as indicated before. Fig. 22 shows the luminosity of the colours in the spectrum of the light from the positive pole of the electric light. Coming to the question of the total luminosity of the two sectors, we have the area of the chrome yellow = 464, whilst that of the blue = 93. The sum of the two is 557. As the angular value of the yellow sector is 169, this value has to be reduced by 169/360 = ·47, and is 261·7.

The angular value of the white sector used in the match discs was 158·5. As the black reflected ·0833 of white light, the total value of the rotated white was (158·5 + 201·5 × ·0833, or) 175·4. The area of the curve of luminosity of the white being 534, the luminosity of the grey was 175·4/360 × 534 = 260·4, a value very near to that found as that of the rotating coloured sectors. The fact that we are only, in this case, dealing with two colours, and that these colours are fairly luminous, makes the calculated and observed values of the greys in the two discs less liable to differ than when the colours are more in number and of less luminosity.

§ XXXVII. *Photographs of the Rotating Discs.*

The next experiment made was to ascertain if the effect of equality of grey produced on the eye when the coloured and black and white sectors were rotated would be shown if they were photographed together.

Fig. 23.



The above figure shows the impression produced on a photographic plate by rotating green, red, and blue sectors, which were kept of the same angular value respectively as given in § XXXIII., as were also the white and black sectors. They were illuminated by the electric light, and photographed on a bromo-iodide plate. It will be seen that there is a falling off of luminosity in the combination of the coloured sectors, an effect which might have been predicted from the Curve V. in fig. 16, in which there is a falling off of intensity in the violet. This shows itself in the photograph, since the plate is but little sensitive below F towards the red.

§ XXXVIII. *Matches by Colour-blind People.*

This experiment suggested that it would be of great interest to try what results would be obtained by a colour-blind person using the same three sectors. R., who had so kindly helped us before (see "Colour Photometry," Part I., § XVI.), again came to our aid and made observations. He was totally deficient in the perception of red, and mistook the vermilion disc for dark green when we showed it to him. The total absence of red perception in him enabled him to match green and blue rotating sectors against black and white sectors. He obtained a balance when the blue sector was 115, the green 245, and the white sector when corrected 134·8. Since the

vermilion appeared to him as dark green, the only effect of introducing the red sector into the coloured disc was to lower the total luminosity, and to diminish the quantity of green necessary to produce with the blue a balance against the black and white discs. Thus, with 126° of the vermilion card, 103° blue and 131° green matched 99°·5 white; and, with 188° vermilion, it required 110° blue and 62° green to match 91°·5 white.

In our former paper we gave R.'s spectrum curve, which indicated the proportion of light which he receives from each part of the spectrum, as compared with normal sight. Fig. 24 shows the curves of luminosity of the light reflected from the coloured sectors, and the same reduced so as to correspond to R.'s sight are indicated by dotted lines. The next table gives the numerical results of this reduction.

Scale.	I_1.	II_1.	III_1.
44·00	·07	·6	·08
44·50		1·5	
45·00	·44	3·8	·32
45·20		5·9	
45·50	2·40	10·1	·89
45·80	4·10	13·5	1·28
46·00	6·10	17·0	1·78
46·35	11·40	21·0	2·62
46·85	22·00	20·0	3·85
47·10	26·00	16·5	4·38
47·35	30·00	9·9	4·86
47·50	33·50		
47·85	35·00	7·5	5·07
48·90	46·50	5·3	5·60
49·40	47·00	4·2	5·70
49·90	35·50	2·8	6·00

The areas of the reduced curves are—green 172, vermilion 60, and ultramarine 36. The angular values of the sectors, it will be remembered, were 133·7, 96·6, and 129·7. Taking the areas to represent values of luminosity, R.'s values *per* 1° *of sector* are—emerald green 1·286, vermilion ·621, French ultramarine blue ·278. The area of the normal curve for white, as stated above, is 534, representing 133°·7. The area of R.'s curve is 343, giving a value of 2·566 for 1°.

Applying these values to the observations, we find a very close correspondence when the two colours were used, but not quite so close when the red was introduced. The angle of white in R.'s observations was 135°·7, which, multiplied by 2·566, gives 346 as the value of the luminosity. The value of the blue luminosity is 115° × ·278 or 32, of the green 245° × 1·286 or 315; and these added together make 347, which is very close to the value obtained for the white.

In the second observation similar calculations will make the value of the white 255,

and of the coloured sector 275. In the third observation they are 235 and 247 respectively. (The dotted lines in fig. 18 show the luminosity curves of the different colours for R. on the normal scale of wave-lengths.)

§ XXXIX. *Comparisons by Gas Light.*

Our observations were extended to gas light comparisons. Our first endeavour was to obtain a comparison between the intensity of the crater of the positive pole of the electric light and gas. In order to do this we used a collimator, as described in No. 232 of the 'Proceedings of the Royal Society,' 1884. On one slit the light of the positive pole was focussed by means of a lens, whose aperture was reduced to about 1 mm. in diameter; on the other was focussed the brightest part of the flame of gas in an ARGAND burner. The spectra from the two sources appeared on the focussing screen of a camera, one above the other, and just touching. A card with a slit was passed through the spectra to isolate any part required. The two spectra were viewed by a RAMSDEN eye-piece, and the intensity of the electric light reduced by means of the movable rotating sectors we have already described till equality was established. In the brightest parts of the spectrum the light was too intense to be readily compared; so, in order to diminish the brightness, a photographic plate, on which an even grey tint had been produced by development, was interposed between the eye and the eye-piece. The light would then be sufficiently reduced in intensity to allow fairly accurate and concordant measures to be made. It may be here remarked that a series of three tints was prepared, from a very light grey, which cut off about 1/4th of the light, to one which cut off 19/20ths, and according to the brightness of the part of the spectra under measurement, so was the darkness of the interposing glass increased. There is an intensity in each case which gives the greatest facility of accurate measurement, and this we endeavoured to obtain. (For the sake of convenience, in the following table the ordinates of the luminosity curve of the light reflected from white card have been increased in such a proportion that the total luminosity from the gas light is equal to the total luminosity found for the electric light. The curves of the colours have been calculated on the assumption that, as before, the white sector had an angular value of 133·7.)

Gas Light.

Scale.	Intensity as compared to electric light.	Luminosity.				Luminosity to a colour-blind person.			
		White card, 133°·7.	Emerald green, 148°.	Vermilion, 119°.	French ultramarine, 93°.	Emerald green, 148°.	Vermilion, 119°.	French ultramarine, 93°.	White card, 133°·7.
43·0	100·0	4·60	·25	2·25	·16	0	0	0	0
44·0	82·0	29 80	2·48	23·30	1·88	·15	1·42	·11	1·80
44·5	74·0	62·70	5·60	52·80	3·13	·39	3·70	·22	4·35
45·0	67·0	99·00	8·80	84·30	4·17	·75	7·15	·35	8·40
45·5	61·0	117·00	20·60	97·10	4·99	3·68	17·20	·89	20·80
46·0	56·0	118·50	26·80	83·10	5·04	8·30	25·80	1·56	41·80
46·5	50·5	113·00	34·40	59·00	4·72	17·40	29·90	2·40	57·50
47·0	45·5	104·00	40·20	33·20	4·52	28·10	23·20	3·20	73·00
47·5	42·0	96·00	45·50	12·90	4·52	35·60	10·10	3·50	75·00
48·0	38·2	83·00	48·30	8·60	4·25	39·50	7·20	3·60	69·50
48·5	35·0	70·20	45·00	6·70	3·70	38·40	5·70	3·20	60·00
49·0	32·5	59·30	42·70	5·20	3·30	38·50	4·70	3·00	53·50
49·5	30·0	45·70	35·60	3·65	3·00	33·90	3·50	2·85	43·50
50·0	28·0	27·30	23·50	2·05	2·75	23 50	2·05	2·75	27·30
51 0	23·5	10·50	8·35	·67	1·54	8·35	·67	1·54	10·50
52·0	20·2	4·30	3·20	·23	·88	3·20	·23	·88	4·30
53·0	17·5	2·20	1·34	·11	·52	1·34	·11	·52	2·20
54·0	15·0	1·21	·53	·06	·33	·53	·06	·33	1·21
55·0	12·7	·75	·20		·16	·20		·16	·75
56·0	10·7	·37							
	Areas	534·00	199·00	238·00	27·60	143·40	71·50	16·00	282·00

The second column of the above table gives the comparative intensity of the gas light we used, taking the intensity of all the rays in the electric light as 100 (see Plate 22, fig. 25). The rapid loss of intensity towards the blue evidently would much modify the quantities of red, blue, and green necessary to match the black and white sectors when compared in light of this description. The other columns of the table give the ordinates of the calculated luminosity curves of fig. 26.

The three sectors were matched as before by us in this light, and it was found that 148° green, 119° red, and 93° blue were required to balance 116° of white.

The area of the curve for the white representing a sector of 133°·7, as before, is 534 that for 116° would therefore be 116/133·7 of 534, or 464.

The areas of the curves of the three coloured sectors on the above proportion are as follows:—Emerald green 199, vermilion 238, French ultramarine 27·6, making a total of 464·6.

We also tested R. by gas light with the same three coloured discs. The red being the same as the green to him, we varied the red at pleasure, and got the following results:—

With green 62, blue 110, red 180, he matched 92 white.

His areas for the above would have been 60, 19, 112 respectively, making a total of 191. The area for the white would be 194.

Again, with green 138, blue 94, red 128, he required white 106. The areas would have been as follows: 133·5, 16, and 77 respectively, or a total of luminosity 226·5. The luminosity of the white used was 223.

Again, with blue and green alone, he required 288 green and 72 blue to match 141 white. The areas of the above were 281 and 12·4 respectively, or a total luminosity to him of 293·4. The luminosity of the white used was 297·4.

§ XL. *Comparison of Gas Light, Sky Light, and the Electric Light.*

Fig. 24 (Plate 2) shows the proportions of the different rays in sky light, gas light, and the electric (crater) light, the last being taken as the standard of comparison. The sky measured, it may be stated, was a fairly blue sky and not very pale. The light diffused through a cloud on a cloudy day in April we have found to be almost exactly similar to the light of the electric arc, and, in fact, is degraded sun light.

We have shown how the three coloured sectors vary in proportion to form a grey when examined by electric light and by gas light. The variation would be even greater when sky light of the blue shown was employed. On a cloudy day, however, the proportions of each colour would be approximately the same as found for the electric light. It is evident that for quantitative measures for testing light no reliance can be placed on the results, unless light of an uniform character be always employed. Day light, being composed of variable amounts of sun light and sky light, should, in all cases, be avoided.

§ XLI. *Reflection of Light from Metals.*

As a matter of curiosity, we wished also to determine the intensities of the different rays reflected from some of the metals which were coloured. We took ordinary polished copper, such as is supplied in commerce for etching purposes; a piece of the same copper highly burnished; a piece of highly burnished brass; and a piece of highly burnished gold. Fig. 27 (Plate 21) and the following tables give the result. In the figure the continuous lines show the luminosity curves, and the dotted lines the intensity curves.

Highly Polished Copper.

Original readings.		Reduced from plotted curve.			Luminosity.	
Scale number.	Reading.	Scale number.	Height.	Height when white = 100.	Height of white curve.	Height of copper curve.
42·80	51·0	43·0	51·0	73·9	2·0	1·45
43·30	51·0	43·5	51·0	73·9	5·0	3·64
44·30	51·0	44·0	51·0	73·9	16·0	11·70
44·80	51·0	44·5	51·0	73·9	37·0	25·80
45·85	50·0	45·0	51·0	73·9	65·0	48·00
46·85	47·0	45·5	50·5	73·2	84·0	63·30
47·85	41·0	46·0	49·7	72·1	93·5	67·20
48·90	37·0	46·5	48·0	69·6	98·5	68·50
49·90	35·0	47·0	46·0	66·7	100·0	66·60
50·95	34·0	47·5	44·0	63·8	99·0	63·10
51·95	33·5	48·0	41·0	59·5	95·0	56·40
53·00	33·0	48·5	39·2	56·8	88·0	50·00
54·50	32·0	49·0	36·5	52·9	80·0	42·30
57·05	30·0	49·5	35·5	51·4	67·0	34·50
58·05	30·0	50·0	35·0	50·7	43·0	21·80
		51·0	34·0	49·3	19·5	9·60
		52·0	33·5	48·6	9·5	4·70
		53·0	33·0	48·0	5·5	2·60
		54·0	32·5	47·3	3·5	1·63
		56·0	31·0	44·9	1·5	·66
		58·0	30·0	43·5	·6	·26

Burnished Copper.

Original readings.		Reduced from plotted curve.			Luminosity.	
Scale number.	Reading.	Scale number.	Height.	Height when white = 100.	Height of white curve.	Height of copper curve.
42·20	80·0	43·0	75·0	94·0	2·0	1·9
43·25	72·0	43·5	72·0		5·0	
44·00	60·0	44·0	62·0	77·5	16·0	12·4
44·80	53·0	44·5	56·0	70·0	37·0	25·9
45·30	47·0	45·0	50·0	62·5	65·0	40·6
45·80	43·0	45·5	45·0	56·2	84·0	47·7
46·60	37·5	46·0	41·0	51·2	93·5	47·9
47·50	29·5	46·5	37·0	46·2	98·5	45·5
48·50	25·0	47·0	32·5	40·5	100·0	40·6
48·70	24·0	47·5	29·5	37·0	99·0	36·8
49·40	22·0	48·0	27·0	33·7	95·0	32·1
52·00	17·0	48·5	25·0	31·0	88·0	26·9
54·60	14·5	49·0	23·5	29·5	80·0	23·5
56·20	14·0	49·5	21·5	27·2	67·0	18·8
58·70	14·0	50·0	21·0	25·5	43·0	11·3
		51·0	19·0	23·0	19·5	4·6
		52·0	17·0	21·2	9·5	2·0
		54·0	15·0	18·7	3·6	·7
		56·0	14·0	17·5	1·5	·3
		58·0	14·0	17·5	·6	·1

Highly Polished Brass.

Original readings.		Reduced from plotted curve.			Luminosity.	
Scale number.	Reading.	Scale number.	Height.	Height when white = 100.	Height of white curve.	Height of brass curve.
43·30	57·0	43·0	57·0	82·60	2·0	1·60
43·80	57·0	43·5	57·0	82·60	5·0	3·80
44·30	57·0	44·0	57·0	82·60	16·0	13·00
44·80	56·0	44·5	57·0	82·60	37·0	30·10
45·60	54·5	45·0	56·0	81·20	65·0	52·80
46·85	55·5	45·5	56·0	78·30	84·0	65·70
47·85	53·5	46·0	55·0	79·75	93·5	74·50
48·85	52·5	46·5	55·5	80·47	98·5	79·20
49·90	49·0	47·0	55·0	79·75	100·0	79·70
50·95	46·0	48·0	54·0	74·30	95·0	74·30
51·95	42 0	48·5	53·0	76·90	88·0	67·60
52·95	39·0	49·0	52·0	75·45	80·0	60·30
54·00	37·0	49·5	51·0	74·00	67·0	49·50
55·50	34·0	50·0	49·0	71·10	43·0	30·50
57·00	30·5	51·0	45·0	65·20	19·5	12·70
58 00	28·5	52·0	41·5	60·20	9·5	5·70
		53·0	39·0	56·50	5·5	3·10
		54·0	37·0	53·60	3·5	1·90
		56·0	32·0	46·40	1·5	·68
		58·0	28·0	40·60	·6	·24

Gold.

Original readings.		Luminosity curves.	
Scale number.	Reading.	Height of white curve.	Height of gold curve.
43 5	29·0	5·0	1·45
44·0	35·0	16·0	7·60
44·5	40·0	37·0	14·80
45·0	44·0	65·0	28·60
45·5	46·5	80·0	37·20
46·0	48·5	93·5	42·80
46·5	50·0	98·5	49·20
47·0	51·0	100·0	51·00
47·5	51·0	99·0	50·50
48·0	51·0	95·0	48·50
48·5	50·5	88·0	44·40
49·0	49·5	80·0	39·60
49·5	48·0	67·0	32·20
50·0	46·0	43·0	19·90
51·0	41·0	19·5	8·00
52·0	35·0	9·5	4·30
53·0	31·0	5·5	1·70
54·0	27·0	3·5	·61
55·0	24·0	2·1	·49
56·0	21·5	1·5	·32
58·0	16·0	·6	·09

The intensities were obtained by substituting for the first small glass prism in front of the slit a piece of the metal whose reflection was to be examined. The two images were received on a white screen and equality established, as before described. A very interesting confirmation of the accuracy of measuring the illuminating value of different light was found in the case of burnished copper. In 1886 the "luminosity curve" of the spectrum of the light reflected from copper was obtained, the piece of copper used being part of the same plate from which the intensity curve was obtained in our recent experiments. The dots close to the curve of luminosity derived from the intensity curves show the agreement of the results obtained by two very different methods. In the same year the luminosity curve of emerald green was made by our former plan, and on reducing the curve in the proper proportion, so that the maximum coincided with the maximum of the luminosity curve obtained from the comparison of the intensity of light reflected from the emerald green with that from a white surface, it was found that the agreement was extremely close. These coincidences confirm the accuracy and value of our method of measuring the luminosity of light of different colours.

§ XLII. *Comparison of Reflection from, with Transmission through, a Pigment.*

We wished also to ascertain whether the light reflected from a pigment was identical with that transmitted through the same. In some cases, when there is quasi-metallic reflection, in parts this cannot be the case; but in ordinary colours this reflection is not present. We tried several, and came to the conclusion that the transmitted and reflected lights are of the same character. Fig. 28 gives the result of one such experiment made with Prussian blue. The transmitted light was measured by placing in the lower spectrum a thin film of gelatine impregnated with the pigment. The curves of the figure were constructed from the following table.

Scale number.	Transmitted light.		Reflected light.	
	Reading.	Reduced to white = 100.	Reading white = 100.	Calculated intensity less white.
43	4·0	4·6	23	1·8
44	5·0	5·7	24	3·6
45	6·0	6·9	25	5·4
46	10·0	11·5	28	10·9
47	16·5	19·0	33	19·0
48	25·5	29·3	38	29·9
49	34·0	39·1	44	39·8
50	42·5	48·9	50	50·7
51	51·0	58·6	56	61·5
52	60·0	69·0	62	72 4
53	66·5	76·5	65	77·8
54	68·0	78·2	66	79·6
55	69·0	79·3	66	79·6
56	69·0	79·3	65	77·8
57	70·0	80·5	64	76·0
58	70·0	80·5	64	76·0

A certain amount of white light being reflected from the coloured surface, a correction is necessary for this, and the last column was derived from the preceding one by deducting 22 (the amount of white light present) and multiplying by 1·81.

§ XLIII. *Intensity Curves of Coloured Pigments.*

Figs. 29 (Plate 22) and 30, 31, 32 (Plate 23) give the curves of some of the many colours which have been measured by the method described in this paper. These curves are plotted to the normal scale of wave-lengths, and the following tables give the readings at the different wave-lengths.

Vermilion.	Carmine.	Venetian red.	Mercuric iodide.	Indian red.	Scarlet lake.
4350 = 6·75	4300 = 37·00	4200 = 22·5	4300 = 3·0	4200 = 25·7	4250 = 36·5
4800 = 6·75	4500 = 38·50	4300 = 25·0	4500 = 2·0	4300 = 27·0	4400 = 34·0
5000 = 7·50	4550 = 39·00	4400 = 27·7	4600 = 4·0	4500 = 29·5	4500 = 32·5
5300 = 9·50	4700 = 36·50	4500 = 29·5	4750 = 5·8	4750 = 30·5	4600 = 31·7
5500 = 11·50	4800 = 34·50	4550 = 30·0	4900 = 4·2	4900 = 30·0	4700 = 30·5
5600 = 15·00	5000 = 32·00	4750 = 30·0	4950 = 3·5	5000 = 29·3	4800 = 28·2
5750 = 31·50	5100 = 31·00	5000 = 30·5	5000 = 3·7	5150 = 29·0	5000 = 25·5
5800 = 40·00	5200 = 31·50	5200 = 31·5	5200 = 5·5	5300 = 30·0	5150 = 25·0
5900 = 59·00	5300 = 33·00	5300 = 32·5	5400 = 6·8	5400 = 31·5	5200 = 25·2
6000 = 78·00	5380 = 34·50	5400 = 34·5	5500 = 8·0	5500 = 33·5	5300 = 26·0
6200 = 97·00	5450 = 33·50	5500 = 39·5	5700 = 18·0	5600 = 36·3	5500 = 29·5
6500 = 94·50	5550 = 33·25	5600 = 47·0	5750 = 22·0	5750 = 42·5	5600 = 34·0
6600 = 90·50	5600 = 34·00	5700 = 58·0	5800 = 29·5	5800 = 48·5	5700 = 41·0
6750 = 84·00	5700 = 41·00	5750 = 61·0	5900 = 54·5	5900 = 52·0	5800 = 50·5
7000 = 72·50	5800 = 50·00	5800 = 65·0	6000 = 66·5	6000 = 58·5	5900 = 62·0
	5900 = 59·00	5900 = 72·0	6100 = 70·0	6100 = 63·2	6000 = 76·0
	6000 = 67·00	6000 = 78·5	6200 = 71·7	6200 = 66·5	6100 = 82·0
	6100 = 70·50	6100 = 83·5	6300 = 73·5	6250 = 67·5	6200 = 82·0
	6200 = 72·50	6200 = 87·5	6400 = 74·5	6400 = 70·6	6300 = 81·5
	6300 = 74·00	6300 = 90·5	6500 = 75·4	6500 = 72·5	6400 = 80·6
	6400 = 75·00	6400 = 92·2	6600 = 75·8	6990 = 76·0	6500 = 80·0
	6500 = 76·00	6500 = 93·3	6750 = 76·3		6800 = 77·3
	6600 = 75·00	6620 = 94·0	7000 = 76·3		
	6800 = 72·00				

Emerald green.	Chrome green.
4200 = 25·00	4250 = 16·0
4300 = 25·75	4400 = 17·6
4500 = 29·00	4600 = 20·2
4600 = 34·50	4800 = 22·6
4700 = 49·00	4900 = 26·0
4800 = 60·00	5000 = 30·5
4900 = 68·00	5100 = 36·0
5000 = 72·50	5200 = 42·0
5125 = 75·00	5300 = 44·6
5200 = 73·50	5310 = 45·0
5300 = 69·50	5400 = 43·5
5400 = 63·00	5500 = 40·5
5500 = 55·50	5600 = 35·0
5600 = 47·50	5700 = 22·0
5700 = 39·70	5750 = 20·5
5800 = 32·00	5850 = 19·8
5900 = 26·00	6000 = 20·5
6000 = 20·50	6200 = 24·0
6100 = 16·50	6300 = 26·0
6200 = 13·40	6450 = 32·0
6300 = 10·00	
6400 = 9·00	
6500 = 8·00	
6600 = 7·60	
6750 = 7·00	
7000 = 6·50	

French ultramarine.	Prussian blue.	French blue (pale).	Cobalt blue.
4350 = 38·00	4200 = 60·50	4250 = 40·00	4350 = 44·0
4600 = 38·00	4500 = 67·00	4400 = 47·00	4500 = 51·7
4750 = 35·00	4600 = 68·00	4500 = 54·00	4600 = 53·3
4900 = 27·00	4800 = 64·00	4600 = 61·00	4700 = 54·0
5000 = 21·50	5000 = 59·00	4625 = 61·25	4800 = 53·6
5200 = 12·50	5250 = 49·50	4700 = 60·50	4900 = 50·5
5500 = 8·00	5500 = 41·75	4750 = 58·50	5000 = 41·5
5750 = 7·00	5800 = 34·50	4900 = 48·00	5100 = 29·0
6300 = 6·85	6000 = 30·00	5000 = 43·70	5200 = 20·0
6500 = 7·50	6300 = 25·50	5100 = 40·20	5300 = 15·0
6620 = 8·50	6500 = 23·50	5200 = 36·50	5400 = 11·5
7000 = 6·50	6800 = 22·00	5400 = 31·00	5500 = 8·5
	7000 = 21·00	5750 = 24·30	5600 = 6·5
		5850 = 24·00	5750 = 6·0
		6000 = 25·20	6000 = 7·5
		6200 = 28·20	6100 = 10·5
		6300 = 30·20	6200 = 14·0
		6400 = 32·70	6300 = 18·5
		6500 = 34·50	6400 = 23·5
		6600 = 36·50	6500 = 28·5
		6700 = 37·50	6600 = 34·5
			6700 = 40·0

Chrome yellow.	Aureolin.	Cadmium yellow.	Yellow ochre.	Gamboge.
4350 = 30·0	4250 = 15·0	4200 = 21·5	4375 = 15·50	4275 = 15·0
4500 = 30·7	4350 = 13·0	4400 = 22·5	4500 = 21·55	4300 = 14·5
4600 = 32·5	4400 = 14·0	4500 = 23·5	4550 = 21·60	4375 = 13·7
4700 = 37·5	4500 = 15·7	4700 = 28·0	4600 = 21·00	4500 = 16·0
4750 = 44·5	4600 = 16·2	4800 = 32·0	4750 = 21·70	4550 = 17·5
4800 = 51·5	4700 = 19·0	4900 = 37·0	4800 = 23·00	4600 = 18·0
4900 = 61·5	4800 = 25·0	5000 = 42·0	4900 = 25·50	4650 = 18·5
5000 = 68·5	4900 = 33·0	5100 = 49·5	5000 = 29·30	4750 = 21·5
5100 = 76·5	5000 = 42·0	5200 = 57·5	5100 = 34·00	4900 = 28·5
5200 = 80·5	5100 = 53·0	5300 = 65·0	5200 = 40·50	5000 = 36·5
5300 = 86·5	5200 = 65·0	5400 = 73·0	5300 = 49·00	5200 = 53·5
5400 = 91·5	5300 = 75·5	5500 = 80·5	5400 = 59·00	5250 = 57·5
5500 = 95·0	5400 = 83·0	5600 = 88·5	5500 = 67·50	5300 = 60·5
5550 = 96·0	5500 = 89·0	5700 = 91·5	5600 = 75·50	5400 = 67·5
5600 = 94·5	5600 = 92·7	5800 = 93·5	5750 = 79·50	5500 = 73·0
5750 = 89·5	5700 = 93·5	5900 = 94·6	5800 = 80·00	5700 = 75·5
5870 = 87·0	5800 = 94·0	6000 = 95·0	5875 = 79·00	5900 = 78·5
6000 = 89·5	6000 = 93·5	6100 = 94·0	5900 = 77·00	6000 = 80·0
6100 = 91·0	6150 = 93·0	6200 = 92·0	6000 = 77·00	6200 = 81·7
6200 = 92·0	6300 = 93·5	6300 = 89·5	6250 = 77·50	6350 = 82·0
6300 = 92·0	6400 = 94·0	6400 = 86·7	6300 = 77·50	
6400 = 91·5	6500 = 94·6	6500 = 84·0	6400 = 77·50	
6500 = 91·0	6620 = 96·0	6750 = 77·0	6500 = 77·50	
6700 = 89·5				
7000 = 87·7				

Fig. 18. Luminosity Curves reduced to Normal Scale.

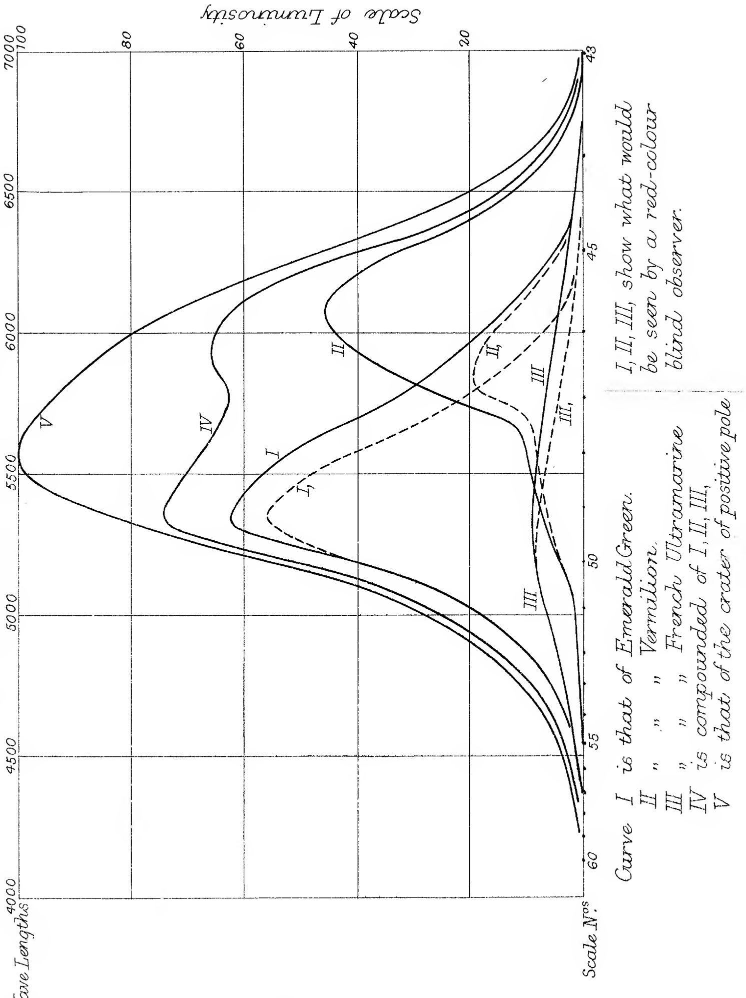


Fig. 19. Mask which when rotated in the Spectrum gives Emerald Green.

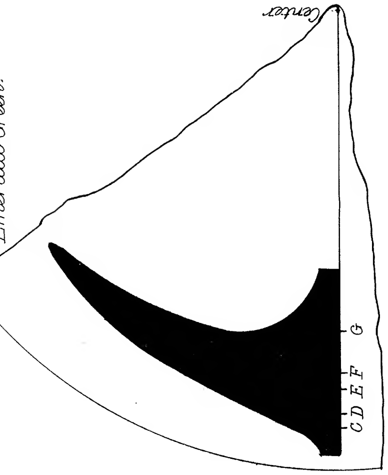


Fig. 20. Mask which when rotated in the Spectrum gives white light.

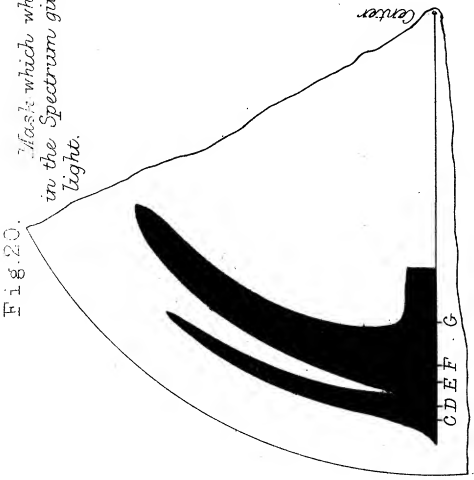


Fig. 16. Intensity Curves.

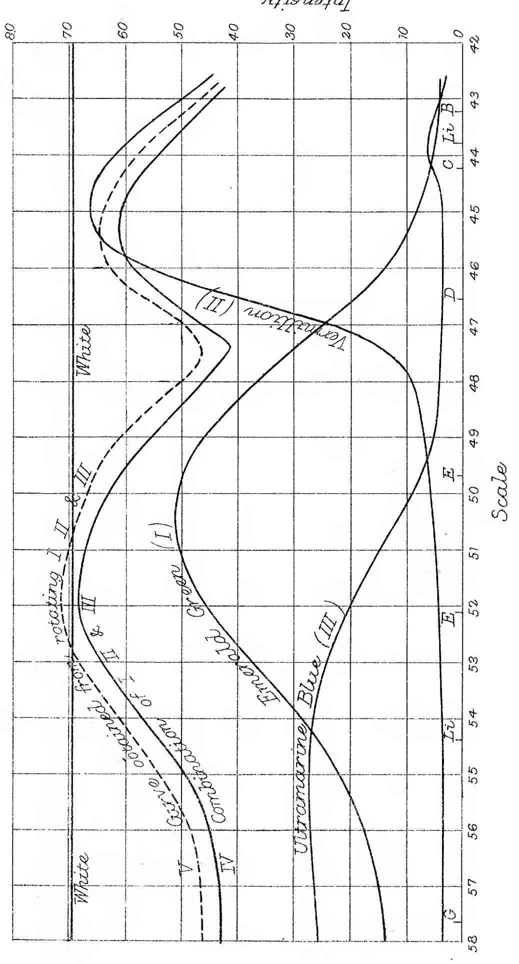
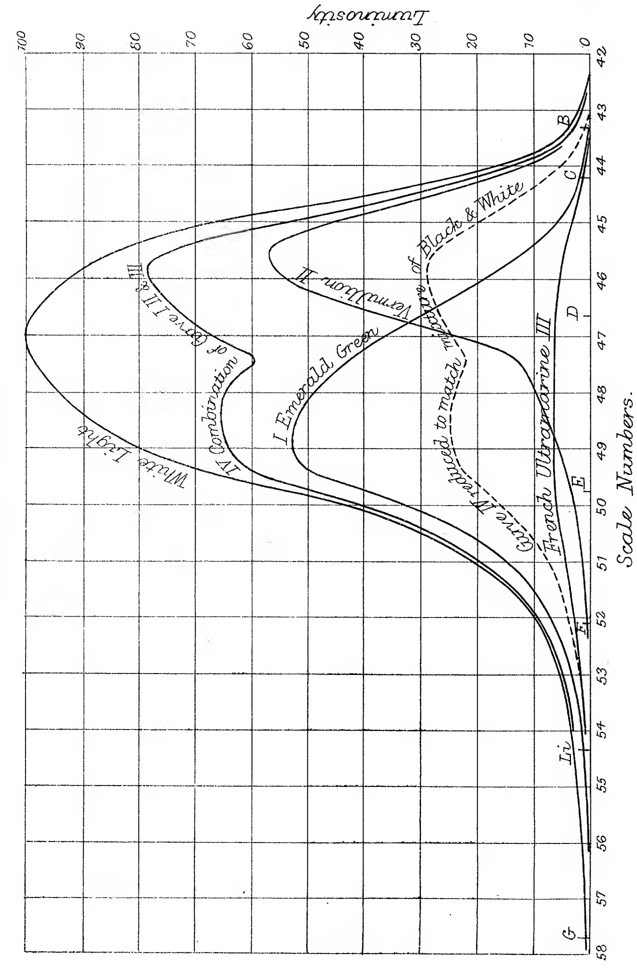


Fig. 17. Luminosity Curves



West, Newman & Co lith.

Fig. 24.

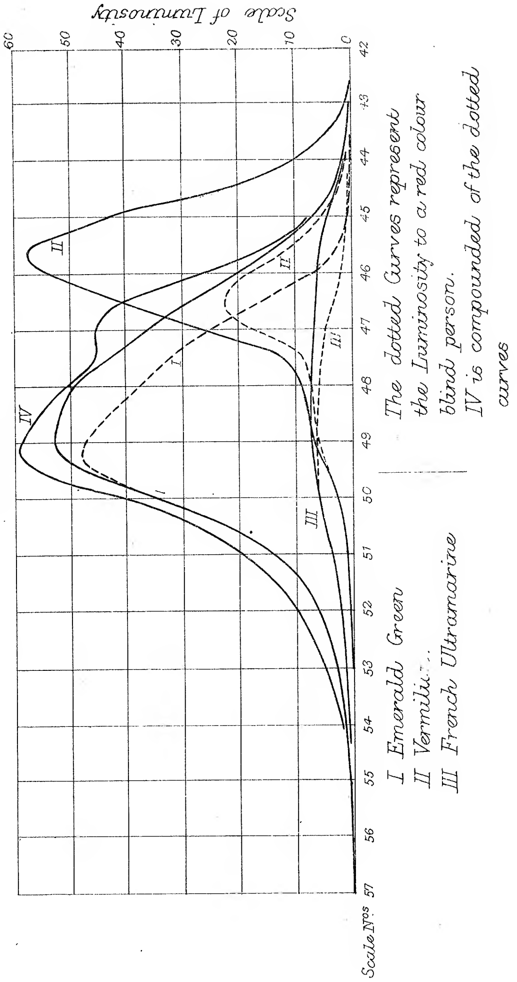


Fig. 27.

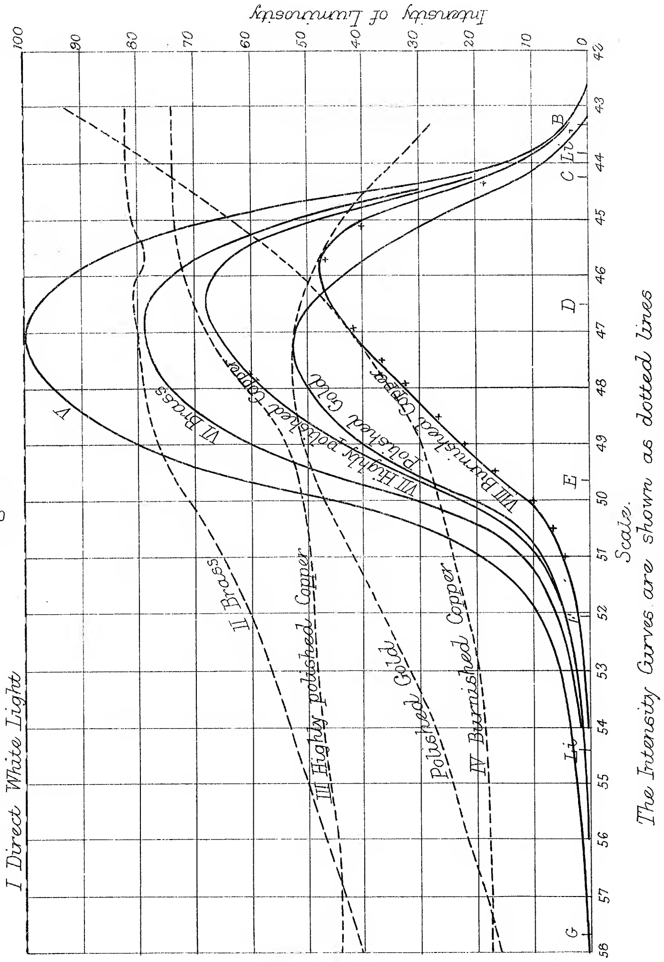


Fig. 21.

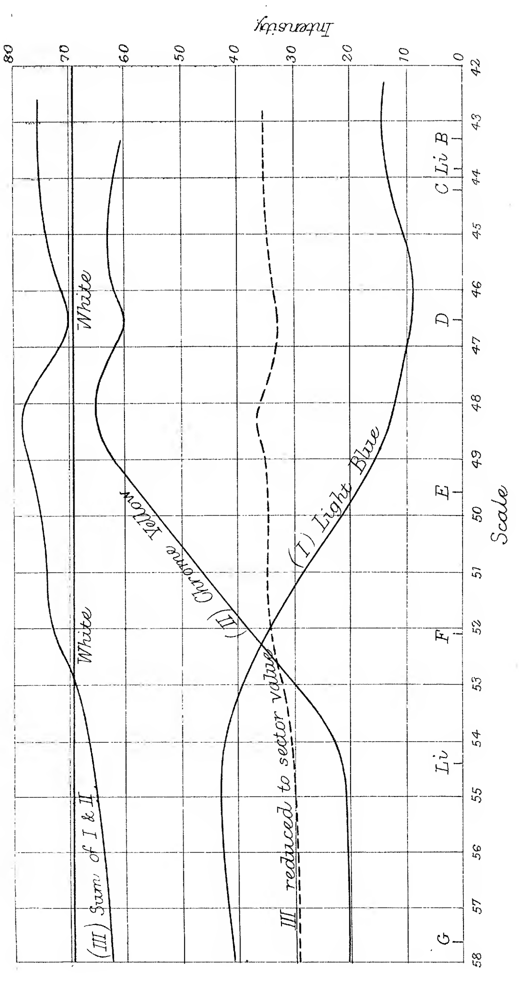
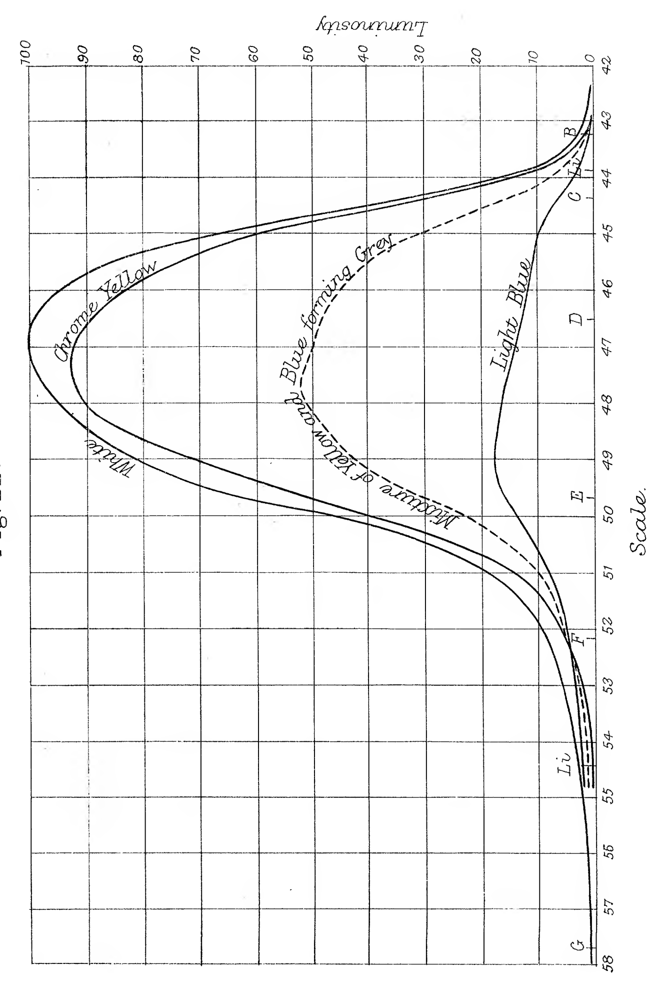


Fig. 22.



West, Newman & Co lith.

Fig. 28.

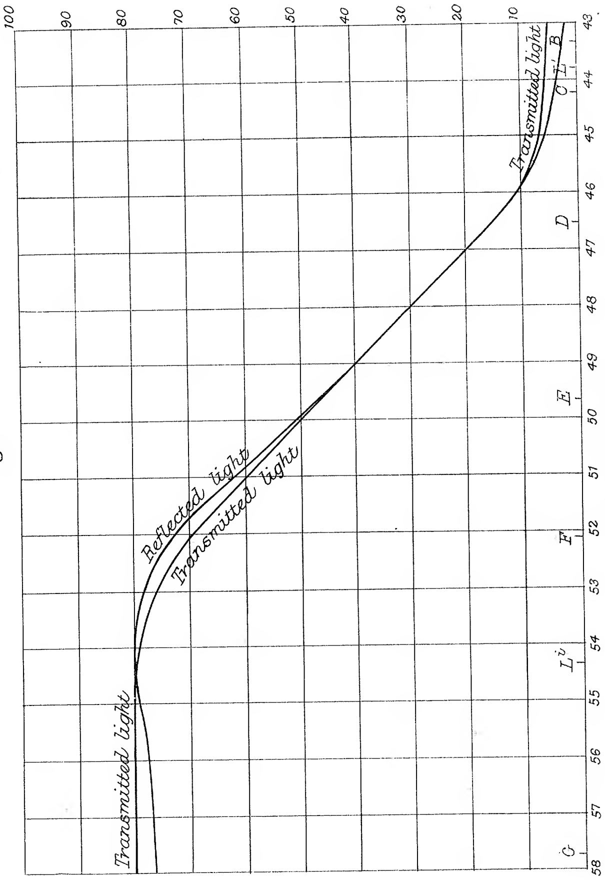


Fig. 29.

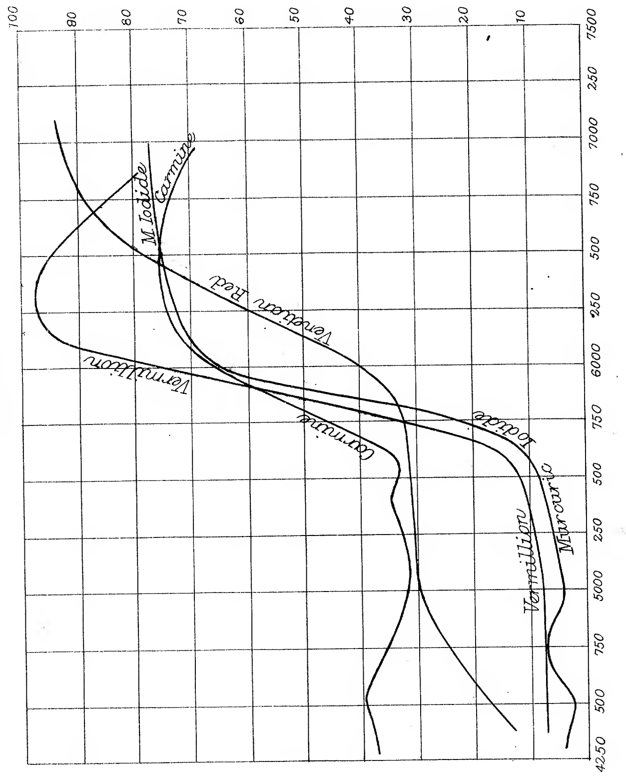


Fig. 26.

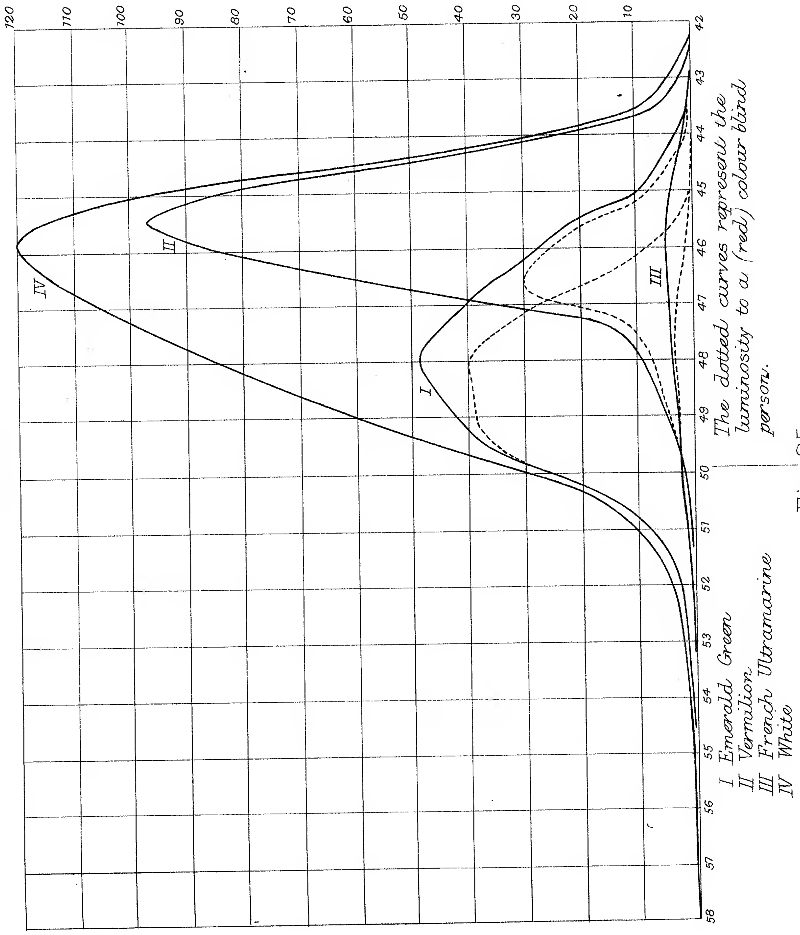


Fig. 25.
Electric Light.

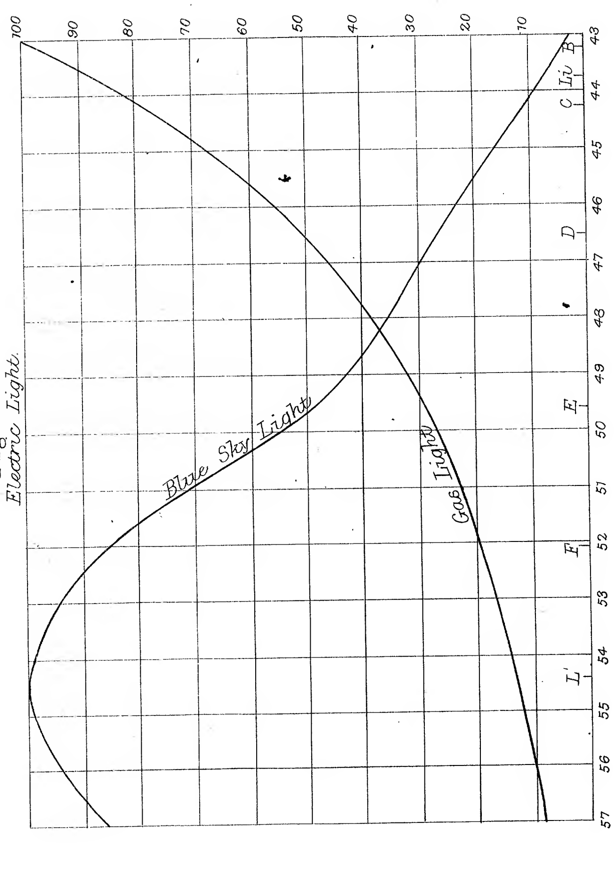


Fig. 30.

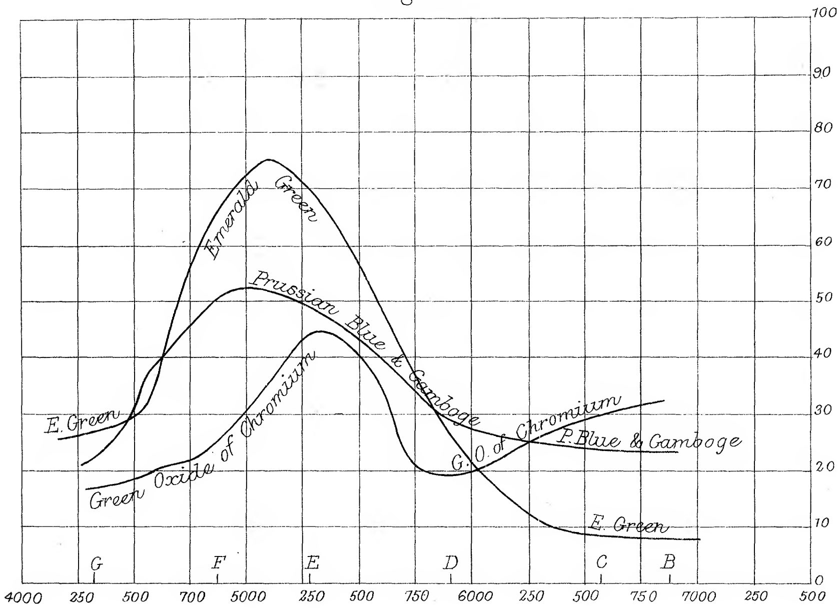


Fig. 31.

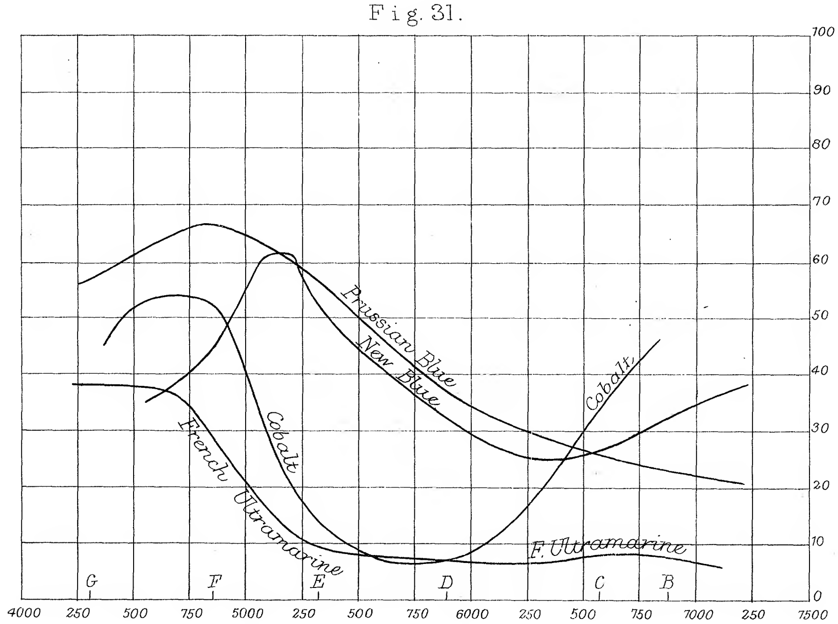


Fig. 32.

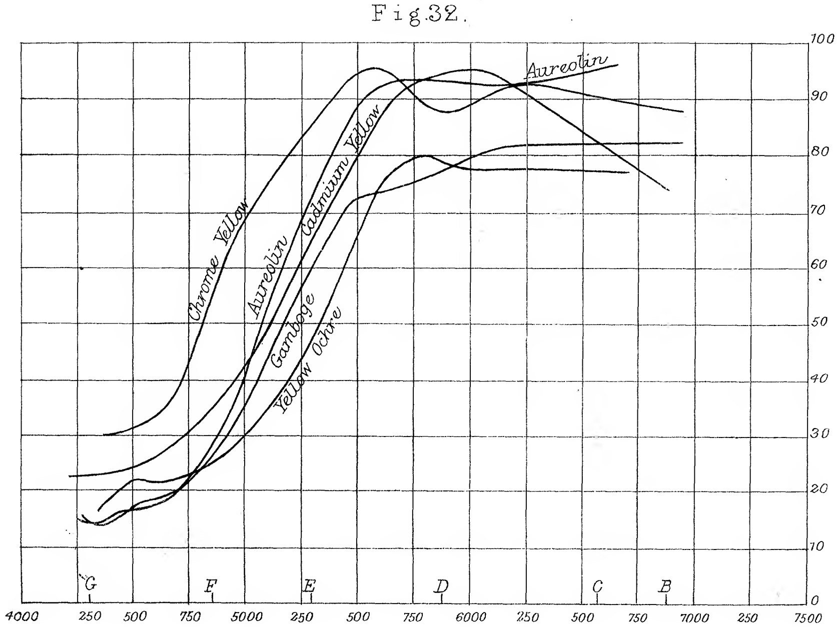


Fig. 23.